Review Report of the RBEP Technical Projects

September 1999

Introduction

The Regional Biomass Energy Program (RBEP) is a federally funded program located in five regions of the United States. Its specific goal is to increase the production and use of bioenergy resources. The RBEP objectives are to:

- Improve state, local government, and industry capabilities and effectiveness in the production and use of bioenergy resources.
- Support planning efforts, particularly assessing current and future biomass resource availability, its use, and applied research needs.
- Encourage economic development through public and private investment in bioenergy technologies.
- Perform applied research and demonstrate bioenergy technologies on a cost-shared basis, reduce or eliminate market barriers, understand economic and environmental costs and risks, and accelerate the market acceptance of bioenergy technologies.

The Office of Fuels Development (OFD) in the Office of Transportation Technologies at the U.S. Department of Energy (DOE) manages the RBEP. The RBEP is also partially funded by the DOE's Office of Power Technologies Biomass Power Program (BPP). A list of RBEP contacts and the states served by each region is provided in Section 8.

The RBEP carries out activities related to technology transfer, infrastructure development, industry support, stakeholder relationships, technology development and demonstration, and matching available bioenergy resources to conversion technologies. With an emphasis on technologies best suited to near?term applications, its major focus is the transfer of current, reliable economic and technical information to potential biomass users.

Activity Arenas

The importance of positive, supportive attitudes towards bioenergy use by government officials and other public policy makers is one vital "lesson learned" from the RBEPs in developing this industry. Developing positive attitudes for bioenergy is based on credible information, public education, and sound technology demonstration. Information regarding the economic and environmental advantages of bioenergy use, resource data and capacity assessments, and the potential applications for new products and technologies made from biomass still needs to be widely shared with a variety of audiences.

Each RBEP generally conducts its activities in two interactive arenas.

- Cooperative initiatives with individual state governments match local opportunities with resources and address area-specific problems to find local solutions.[1] Beyond the potential economic development benefits, participating states have the opportunity to strengthen and integrate the work of energy, forestry, air quality, and other relevant offices in promoting bioenergy use. For some regions, the state grant component is the primary method for conducting development and demonstration projects.
- Region-wide technical projects address issues common to all the member states. For technical projects, each region seeks active cooperation and cost-sharing between the participating states, private industry, trade associations, private farm owners, universities, and other federal agencies. Since its beginning in 1983, the RBEP has been a highly leveraged program. For every federal dollar invested, RBEP partners contribute at least two dollars.

This *Review Report of the Regional Biomass Energy Program Technical Projects* provides a brief narrative of some initiatives being conducted directly by the five regional programs. For its technical projects, each RBEP seeks active cooperation and cost sharing from the participating states, private industry, universities, and other federal agencies. Because there are more than 75 listings in the current RBEP technical project portfolio, there is no opportunity to include many vital projects in the areas of stakeholder relationships, technology transfer, infrastructure development and industry support, or technology development and demonstration.

Liquid Biofuels

The OFD formulates, executes, and coordinates a balanced and customer-focused national program of research, development, and demonstration of technologies for the production of transportation fuels from biomass. The biomass resources considered include agricultural residues, forestry wastes, and crops grown specifically for energy applications. As guided by its multi-year technical plan, two major projects now being carried out within the OFD Biofuels Program include the bioethanol project and the biodiesel project. The RBEP helps the OFD provide the technology and assistance necessary for liquid biofuels to be cost-competitive. The individual regions have worked both to lower biofuel production costs and to increase markets for their use.

Bioethanol

The RBEP has provided cost-shared funding to reduce the cost of producing ethanol by developing and commercializing new technologies, by utilizing alternative waste feedstocks, and by developing new co-products. The RBEP has funded cost-shared projects to create markets for high-blend ethanol. Aviation engines, small engines, heavy-duty engines, and ethanol-powered fuel cells are some ongoing projects.

In some regions, the RBEP was instrumental in ensuring that states acquired a fleet of E-85 flexible fuel vehicles (which run on either gasoline or ethanol blends as high as 85%) and public refueling stations. The states continue to test and evaluate the performance and driveability of these vehicles and will continue to expand their E-85 fleets. However, while many federal and state agencies operate such E-85 vehicles, there is often little E-85 fuel available. As a result, vehicles designed to use E-85 often operate using gasoline.

For example, Kentucky purchased a fleet of 275 E-85 vehicles. To realize the fleet's energy and environmental benefits, it was necessary to develop E-85 refueling stations. With the assistance of the Southeastern RBEP (SERBEP), they were established and are now dispensing a steady volume of blended ethanol fuel.[2] As a result, the director of the state motor pool issued a memo to all state agencies stating that the state's flexible-fuel vehicles are to refuel only with E-85. The SERBEP also worked in Kentucky with the National Park Service (NPS) to establish an E-85 refueling site at Mammoth Cave National Park (MCNP).[3] An ethanol-compatible storage tank was installed and E-85 fuel acquired. MCNP then purchased two E-85 passenger vehicles. The project has allowed the small MCNP fleet to consistently use E-85. In addition to reducing fossil fuel use, the project allows the MCNP to meet the requirements of the Energy Policy Act of 1992 and Presidential Executive Order 1313.

The RBEP has also included a number of other ethanol test and demonstration programs, which evaluate the use of high-percentage blends of ethanol in light-, medium-, and heavy-duty transportation vehicles. Usually E-10 ("gasohol") is the highest ethanol blend used in unmodified cars and trucks.

The use of E-30 (a blend of 30% ethanol and gasoline) in unmodified passenger cars and light duty trucks is one project supported by the Great Lakes RBEP (GLRBEP). A refueling site was set up in Winnebago, Minnesota. Fifteen vehicles from the 1985-1997 model years with four-, six-, and eight-cylinder engines of varying sizes were selected for the E-30 test. Three rounds of emissions testing have been conducted at the emission laboratory at the Minnesota Center of Automotive Research. After the one-year test period, no driveability, material compatibility, or oil breakdown problems were reported. Overall, test results have been very positive, indicating that a higher blend of ethanol is compatible with current automotive engines.

Another GLRBEP project hopes to develop an automated ethanol production unit and fuel cell power plant for producing high-value co-products using corn and waste starch products.[4] This effort will demonstrate a small, automated ethanol production facility where the ethanol will be used to power a laboratory-scale direct fuel cell. The high protein stillage co-product will be directly fed to 3,700 head of cattle. A market assessment and preliminary business plan for commercialization will also be performed. Thus far, ethanol has been produced using both corn and waste starch. Cattle feeding trials using wet stillage have been completed with favorable results. Although use of waste starch with corn presented some increased costs in the feeding and handling system, both feedstocks were positive in all other respects. Ethanol produced at this facility was sent to the fuel cell supplier to use in designing the fuel cell, and an integrated system has been designed for this operation. The developers plan to expand their operation to use biogas generated from an on-site anaerobic lagoon to operate the ethanol production facility. This will create a self-sufficient farm-based system that the developer plans to market.

The GLRBEP is also working with researchers to demonstrate the feasibility of using a hybrid thermal/biological process to convert lignocellulosic material into sugars suitable for fermentation to ethanol.[5] A novel gasifier pilot plant was retrofitted to produce pyrolysis liquids from corn stover and switchgrass, which are rich in complex sugars. This liquid product, referred to as pyrolysis syrup, will be investigated as an ethanol fermentation feedstock. Sugar yields will be assayed, fermentation strategies evaluated, and process costs estimated. Several pure- and mixed-culture pyrolysis syrup fermentations are now being evaluated in stirred-tank bioreactors. Extremophilic anaerobes are also being evaluated in the fermentation of pyrolysis products. The initial process results are very promising.

The Western RBEP (WRBEP) is conducting a project assessing the possibility of developing refuse-to-ethanol plants in Arizona[6]. Specifically, the ethanol plant project will focus on:

- Assessing markets for the products produced by the proposed ethanol plants
- Determining the suitability of municipal solid waste (MSW) as an ethanol feedstock
- Identifying potential locations for the waste-to-ethanol plants
- Analyzing waste-to-ethanol plant economics
- Calculating the value of co-products

To help control wintertime carbon monoxide (CO) emissions from automobiles, the use of ethanol in Arizona is estimated to significantly increase. The current annual demand is 40 million gallons, and that is expected to grow to more than 100 millions gallons per year by 2020. All the ethanol is currently produced out-of-state. Because of population demographics, most is consumed in the greater Phoenix area. The project has already identified 14 landfills that are large enough to economically produce ethanol, representing more than 80% of all of the MSW now landfilled in the state. Most of the landfills are located in the Phoenix area, and recycling this MSW would likely allow more than 125 million gallons of ethanol to be produced annually. Not only would this recycling significantly extend landfill life, it would also reduce the amount of organic materials now causing environmental problems when they degrade in an uncontrolled manner in a landfill.

Based on a scoping study funded by both National Research Energy Laboratory (NREL) and the Southeastern RBEP (SERBEP), a project[7] was conducted that focused on producing ethanol from sugarcane. It examined the possibility of converting an ethanol plant using grain feedstock to sugarcane juice. After the juice is extracted, the remaining bagasse would be burned to generate electricity and heat for thefacility. The project assessed the feasibility of using commercial mechanical sugarcane equipment to harvest unburnt sugarcane on phosphatic clay soil. The conventional practice is to burn sugarcanefields before harvest. This component also helped verify crop and ethanol yields, and the combustion characteristics of the bagasse.

The project determined that growing sugarcane for ethanol and electric power production is an excellent example of closed-loop bioenergy production. The project provided a strong influence supporting the conversion of an ethanol production facility to accommodate sugarcane juice as a feedstock. One benefit to the local economy would be job creation. A project such as this would also provide a use for thousands of acres of marginally useful land in central Florida created by the phosphate mining industry.

Biodiesel

Since the early 1990's, the RBEP has been instrumental in developing biodiesel initiatives. The RBEP has also provided invaluable assistance to municipal governments regarding the use of biodiesel-fueled vehicles, and has assessed the optimal blend of biodiesel in transit buses. The purposes of the RBEP biodiesel fuel and lubricant development initiatives are to develop a cost-competitive, biodegradable, and certifiable diesel fuel substitute with comparable performance characteristics to diesel fuel, but with 25% less air emissions, and at least a 50-fold decrease in toxicity over the conventional fuel.

The GLRBEP is working with the National Biodiesel Board (NBB) to establish retail awareness, demand, and distribution of biodiesel in the Great Lakes marine market. The NBB has established a biodiesel distribution system and is educating marina staff and boat owners about the attributes of biodiesel. The partners want to enable successful market penetration of biodiesel in the Great Lakes region. In addition to local regulatory issues that might affect use of biodiesel, marina staff are being trained in storage and handling procedures. During the summer of 1998, biodiesel was distributed free of charge at five Lake Michigan marinas. Customer surveys indicated a very high level of satisfaction. Biodiesel users were especially pleased with the noticeable reduction in emissions. The NBB developed a series of print advertisements and press releases aimed primarily at boating publications. During the summer of 1999, the number of marinas selling biodiesel will increase, and the advertising campaign will continue.

Rhode Island, which participates in the Northeast RBEP (NRBP), conducted a summer-long biodiesel outreach and demonstration project. A letter from Governor Lincoln Almond invited 30 local marinas to participate in the project. They were asked to sell B-20, a 20% biodiesel blend. A public relations firm developed literature for the marina owners on the benefits of using biodiesel. In spring 1998, the Rhode Island Biodiesel Education and Demonstration project was kicked off at the Newport Used Boat Show. About 100 one-gallon jugs of biodiesel were given to interested boaters, and information was distributed to nearly 500 boaters. Oldport Marine of Newport operated four of its launch boats on B-100 (100% biodiesel) for the summer. Three marinas are now outlets for "on the dock" bulk sale of biodiesel. The project has received much media interest. Additionally, the environmental group Save the Bay will run its new educational service boat using B-100 fuel. As a result of this project, several marinas are now outlets for "on the dock" bulk sale of biodiesel. Additionally, launch and service boats are now using B-100 fuel.

The NRBP used this effort to leverage additional projects evaluating the use of biodiesel in diesel engines and turbines. One project, Emission Testing of Low Blends of Biodiesel in Turbines, had the objective of determining whether low blends of biodiesel (B-10 to B-20) will reduce certain air emissions such as CO, total hydrocarbons (HC), oxides of sulfur (SOx), oxides of nitrogen (NOx) and particulate matter (PM) when used as a turbine fuel. Additionally, the NRBP conducted research on blends of biodiesel and how they affect catalyst performance.

The NRBP has also identified the need for developing a high-speed, lightweight, non-electric locomotive in conjunction with an incentive for its using biofuels. A successful application would provide a demand for an alternative renewable fuel combined with the added advantage that a gas turbine has an inherent clean exhaust. The project objectives are, therefore, to establish the practicality of using a biofuel in a gas turbine locomotive from the standpoint of general compatibility with the turbine, procurement and handling of the fuel, emissions, and projected life-cycle costs. If this project finds merit in the approach, additional phases would include computer simulation of emissions using biofuels, test stand evaluation of a selected biofuel, and an in-service trial.

Another NRBP initiative was aimed at developing a biofuels infrastructure in the Northeast because the availability of biofuel refueling facilities is a barrier to expanded use of ethanol and biodiesel in the region. This activity is a follow up to the NRBP's participation in the Alternative Fuels Corridor Project, the region's Clean Cities programs, and state activities directed to biofuel infrastructure development. The project enables the NRBP to work closely with the states and the various Clean Cities programs in the region to identify how support for the construction of ethanol and biodiesel-refueling stations can occur.

The Pacific Northwest and Alaska RBEP (PNW&ARBP) has extensively tested biodiesel engine emissions and performance on two nearly identical pickup trucks equipped with Cummins 5.9-liter (l) diesel engines. The pickup trucks were on-road tested using B-100 rapeseed ethyl ester (REE) or B-100 canola oil ethyl ester (CEE) for a target of 100,000 miles. The first truck was a 1994 Dodge 2500 series placed into service in January 1994. The vehicle had 1,500 miles on commercial diesel fuel when it was switched to B-100 REE fuel. It reached 100,000 miles of operation on the test fuel in October 1998. The second truck was a 1995 Dodge 2500 series placed in service in March 1995. This truck accumulated 92,838 miles when fuel testing ended in May 1998. The second vehicle was operated by the NPS at Yellowstone National Park (YNP) and was fueled with either B-100 REE or B-100 CEE.

Both vehicles were performance tested at regular intervals on a chassis dynamometer. They were tested for regulated emissions in 1994, 1995, 1998, and 1998. Emissions testing was conducted using the Dynamometer Driving Schedule as promulgated in the Code of Federal Regulations. Emissions data generated included CO, HC, carbon dioxide (CO_2), NOx, and PM. All tests were with a chassis dynamometer capable of transient testing. Both vehicles were tested on B-100 REE, B-20-B-50 blends, and a low-sulfur petroleum diesel reference fuel. The emissions tests showed that using the B-100 REE biodiesel fuel reduced HC by 63%, CO by 48%, and NOx by 12%. However, B-100 REE increased PM by 22% compared to the reference diesel fuel. The catalytic converter had a greater effect in reducing PM emissions from REE biodiesel than it did for petroleum diesel. Also, catalytic converter efficiency was unaffected by biodiesel operation.

Another PNW&A region project demonstrated the commercial use of biodiesel in heavy-duty engines. This was a long-haul, 200,000-mile, operational demonstration using a Caterpillar engine and a Kenworth truck. The over-the-road vehicle was fueled with a B-50 HySEE[8] blend with petroleum diesel. The project was divided into three phases:

- Engine Break-in Emissions Testing addressed engine preparation, performance and emissions testing (for regulated and non-regulated emissions), and sampling and analysis following the U.S. Environmental Protection Agency's (EPA) heavy-duty engine dynamometer protocol.
- Operational Over-the-Road Demonstration included scheduled engine oil and filter changes and analysis, operational performance monitoring and chassis dynamometer testing, and production and supply of the B-50 HySEE fuel.
- End-of-Demonstration Engine Inspection, Emissions and Performance will assess engine (mechanical) impacts or changes, if any, resulting from the use of a B-50 HySEE fuel. This phase includes engine disassembly, inspection, analysis, and rebuild.

The project was initiated in July 1997. The engine performance and emissions testing, using a 1997 Caterpillar 3406E engine, was completed in late-1997. The Kenworth truck recently completed the planned 200,000-mile operational demonstration. Average fuel economy is comparable to normal diesel fuel. The J. R. Simplot Company of Caldwell, Idaho used the vehicle as a commercial long-haul vehicle. The University of Idaho manufactured the HySEE biodiesel by using ethanol and the used cooking oil produced as a result of the French fries processing by Simplot. This used cooking oil creates a high quality HySEE biodiesel.

During late 1997 and early 1998, engine performance and emissions testing were conducted using B-100 HySEE. Additionally, two other biodiesel fuels were tested: B-100% REE and B-50 HySEE. As part of this testing, emission samples were collected and chemically analyzed. The analysis also included bioassay studies of toxic, non-regulated, emission compounds. Measurable levels of mutagenic compounds were present in all of the tested fuels. The emission rates for mutagenic activity were lower for the B-100 REE and B-50 HySEE blends than for the comparison petroleum diesel. The B-50 HySEE emission rate for mutagenic compounds was less than 33% of petroleum diesel. These bioassays of mutagenic activity, along with other chemical analyses, provide a basis for assessing the potential exposure to biodiesel toxic air contaminates. This information provides a significant starting point for evaluating the reduction in exposure level to the toxic compounds from biodiesel fuel engine exhausts. Therefore, the work of the RBEP significantly helps assess potential public health benefits from the use of biodiesel fuels.

Another project from the Southeastern RBEP[9] evaluated how a new type of farm organization called a new-generation cooperative (NGC) could be developed to help develop biodiesel production. NGCs differ widely from conventional cooperatives in both concept and function. The cooperative's objective is to pay the farmer for the value-added it adds to a raw material. The membership is closed, and members must buy equity investment units in the NGCs. Equity units entitle that member to deliver a specific quantity of a commodity to which a value will be added, usually through processing.

NGCs were initiated to add value to a wide range of commodities such as grain and vegetable processing. However, farmers who produce soybeans and feed livestock could benefit most from a community-based, biodiesel plant. This is primarily because the farmer internalizes transaction costs relative to the conventional marketing system by using both the high-protein meal and biodiesel fuel on the farm. Thus, the farmer/feeder maintains ownership of the soybeans and soybean products and is not a "price taker" in selling soybeans and in purchasing high-protein meal. In conclusion, the study found that the biotechnology revolution with enhanced soybean varieties that require identity preservation would eventually culminate in a proliferation of small-scale plants and retained ownership for soybean processing into alternative liquid fuels.

Biopower Application

The BPP formulates, executes, and coordinates a balanced, customer-focused national program for researching, developing, and demonstrating technologies for producing electricity from renewable biomass. The BPP mission is to encourage and help industry develop and validate renewable, biomass-based electricity generation systems that can provide substantial economic and environmental benefits to the nation.

The BPP seeks to enhance economic development opportunities by providing an array of co-products—electricity, fuels, and chemicals—by integrating biopower with high-yielding agricultural systems. In this effort, the BPP encourages the highest standard of stewardship of air, water, and soil resources. The four major project areas now being carried out in the BPP include combustion, co-firing, gasification, and small modular biopower systems.

Co-firing

The RBEP has always viewed large industrial and utility applications as one of the ultimate bioenergy end-use applications. Co-firing biomass and coal can act as a technology bridge to introduce biomass to large energy users, and can ease potential users concerns about supply and technical constraints.

Co-firing refers to supplementing coal use in coal-fired boilers with non-coal fuels. A basic premise of co-firing is that significant changes to the boilers are not required beyond minor modifications or additions to introduce and burn the supplemental fuel, and that the boiler is not significantly "derated" in terms of steam production. To meet these objectives, only limited co-firing of biomass fuels is typically done, with the amount of biomass used ranging from 5%-15% of the total boiler heat input.

The RBEP helped popularize the concept of co-firing waste biomass materials with coal in 1989 when felled trees from Hurricane Hugo were blended with coal. Later that year, another project completed three co-firing test burns with 10%-15% wood sawdust concentrations at power plants using pulverized coal. In later years, extensive collaboration with the DOE's Federal Energy Technology Center resulted in the joint wood co-firing R&D plan project with the BPP and DOE's Office of Fossil Energy, NREL, and Sandia National Laboratory.

Many utilities have the means to co-fire coal with biomass to help cut electricity costs, reduce emissions, and support local economic activity. The NRBP helped to screen coal-fired utility boilers in the Northeast[10] that may be good candidates for co-firing with biomass, thereby establishing a replicable framework to assess these units' co-firing potential. This project identified the four power plants in the 11-state region having the greatest likelihood of successfully co-firing coal and biomass, and then helped those sites implement a full-scale analysis of co-firing by providing preliminary assessments for each site. The report details the phased approach used for selecting the candidate sites and describes the conceptual assessments conducted at each site. The report also provides data on emissions and plant operations from utility co-firing demonstrations, and documents key factors to successful co-firing operations.

From an operating and performance perspective the goal for a successful biomass co-firing project is to obtain cost and emissions reductions but not necessarily efficiency improvements. Based on the report, the objectives of a co-firing project should include:

- Obtaining sufficient biomass supplies at prices at least 20% less than coal prices
- Designing and installing biomass fuel receiving, processing, and combustion systems to minimize boiler efficiency losses to less than 1%
- Providing reliable and automated operation, thus having no impact on equipment and operations downstream of the boiler
- Obtaining value from SOx, CO, and NOx emission reductions.

As a result of efforts of the NRBP and others, a major New York electric utility recently co-fired biomass and coal at three power plants, and continues to co-fire commercially at one other station today. Another utility company in the state is modifying a power plant to enable co-firing biomass. This utility may co-fire at additional plants in the future. Co-firing has also been successfully demonstrated at three large power plants in Pennsylvania.

Despite the success with co-firing biomass and coal at utility power plants, co-firing is rarely practiced at industrial, institutional, and other non-utility coal-fired boilers. Although they tend to be smaller than utility-scale boilers, they may be more numerous and have a geographic distribution that results in significant opportunities for co-firing.

The NRBP and the New York State Energy Research and Development Authority (NYSERDA) sponsored a study[11] to identify strategies for stimulating biomass co-firing at non-utility coal-fired boilers. This report identifies industrial boilers in New York State permitted to burn coal, summarizes key factors affecting co-firing at industrial coal boilers, and suggests next steps the NRBP and NYSERDA could take to help increase co-firing in industrial stoker-fired boilers in the region overall and in New York State specifically.

The SERBEP has also identified a number of current and potential co-firing opportunities with industry. One project[12] helped Kentucky, which has abundant coal reserves. However, a large percentage of this coal has a sufficiently high sulfur content to violate clean air standards when burned to generate electricity. One resolution is to use scrubbers, which are costly. An alternative solution for controlling SO2 emissions in power plants is co-firing coal with wood. For such an operation to be adopted by utilities, however, a reliable supply of wood, obtainable at a suitable price and in conjunction with sound forest management practices, is necessary. A major potential source of wood fuel is unutilized material generated by the wood products and mining industries, including sawdust, slabs, edgings, and trim. Other sources include logging debris and wood cleared from lands before mining. The overall objective of this project was to assess the potential of using primary wood industry (sawmill) waste, secondary wood industry (furniture and other lumber processing) waste, logging debris, and timber removed before surface mining as a biomass fuel source for mixing with coal in electric power generation.

Biopower Systems

The development of small- and medium-sized biomass conversion systems to generate electricity or process heat has made great progress during the past decade. Deployment of these systems by business and institutional users has been a key RBEP initiative. There are new opportunities, especially in the use of systems that can simultaneously solve waste disposal problems while producing energy. Even greater opportunities are emerging with new gasification units that combine hot gas clean up. These systems will be used by the utility sector, and some small gasifier systems are being developed for the export market.

A manual developed by SERBEP[13] provides guidelines for using biomass in fluidized bed combustion and gasification systems. The manual provides an introduction to the two principal types of systems, to biomass fuel preparation equipment, and to fluidized bed applications. Economic, environmental and reliability factors are discussed. About half of the report discusses technical factors, including process performance, equipment design issues, emission limits, fuels and ash, and the use of supplemental fuels.

In most production areas, poultry litter is currently applied to the land as an organic fertilizer. Because it is a bulky material, poultry litter is not economical to haul very far. Therefore, it is most often spread on land near where it is produced. However, this practice has contributed to an excess of nutrients being deposited in the soil in some regions. A project[14] jointly done by the NRBP and SERBEP evaluated the economic and technical feasibility of several energy conversion technologies using poultry-derived fuel (PDF). This project encompassed the following tasks:

- Assessing the energy needs for three classes of energy consumer
- Assessing feedstock processing technology
- Evaluating energy conversion options and developing cases studies
- Assessing the potential use of the technologies

Among other items, the study found that there could be significant benefits from turning poultry litter into PDF. Although there are no "silver bullet" conversion processes, direct combustion at electric generation plants and in industrial gasifiers were identified as promising technologies. By using PDF in energy production, poultry litter can provide added value to the regional economy while simultaneously concentrating valuable nutrients such as potassium and phosphorus in the ash. Therefore, energy projects have the potential to play an economic role in improving nutrient management.

In the West, WRBEP has worked extensively to build support for biomass power at Lake Tahoe with a project to use excess forest residues removed from the lake's basin region as a fuel source to produce electricity at a power plant. The local utility company would then sell the power to others as electricity produced from renewable resources or "green" power. The removal of these excess forest residues will improve forest health and reduce the fire hazard in the Lake Tahoe area. One project task will coordinate biomass harvest activities and the green power development program with the U.S. Forest Service (USFS).

As the major landowner in the Basin, the USFS will play a critical role in forest health restoration activities. The USFS outlined seven specific areas in the Basin for forest health harvesting, with sizes ranging from 13 to 1,050 acres. The project team will work to incorporate the green power program into the USFS's planning efforts. The local utility company has been conducting customer research into green power since 1996, with technical assistance from NREL.

The analysis will better determine customer willingness to pay a premium price for green power generated from Lake Tahoe biomass, and to document the price differential that customers are willing to pay. This will help to judge if a green pricing structure can be developed to pay for the costs of harvesting biomass to meet forest health needs. Another project task will create a market awareness of the Basin biopower program, with the objective of getting potential participants to sign letters of intent to subscribe to the initiative.

In conjunction with NREL and the Electric Power Research Institute, the WRBEP completed a report [15] summarizing the operational information on 20 biomass power plants--18 in the United States, one in Canada, and one in Finland. Although there are certainly others, these plants represent some of the leaders in the industry.

In addition to tracking quantitative information such as capacity factors (19%-106%) and heat rate (11,700-20,000 Btu/kWh), the project described some important qualitative "lessons learned" that may lead to an improved biomass power industry. The highest priority at almost every biomass power plant is to obtain the lowest-cost fuels possible. This involves trade-offs in fuel quality, affects the design and operation of the system and frequently is limited by permit requirements. The fuel yard and fuel feed system are the areas of a biomass power plant that can almost be counted on to have provided significant problems or lessons learned. Most plants covered in this report spent significant time and money during their initial years of operation solving problems such as fuel pile odors and heating, excessive equipment wear, fuel hang-ups and bottlenecks in the feed system, wide fluctuations in fuel moisture to the boiler--or in making changes in the fuel yard in response to market opportunities.

Unprocessed biomass or minimally processed biomass fuels have relatively low energy densities compared to fossil fuels. Biomass residues and wastes are most economically used to meet local thermal energy needs or to produce electricity that can be readily wheeled to other locations. The ability to have waste generators deliver the fuel to the plant site at low cost or at their own expense requires a location very close to the sources of waste.

The most successful biopower projects developed formal or informal partnerships with their key customers and suppliers. The relationship with the utility company that buys the power is usually the most important factor. This may change as generators simply bid their power into a power pool. Cogeneration plants by definition must have close relationships with their steam users. Sometimes there are a few large fuel suppliers (such as sawmills) with whom special relationships are crucial.

The projects covered in this report provide many concrete illustrations of the environmental and economic benefits resulting from the use of biopower. These range from plants providing air quality benefits in rural settings where sawmills used to pollute the air with teepee burners to urban areas that burn urban waste fuels cleanly. Some urban power plants provide district heat as well. Other plants burn agricultural residues cleanly, which formerly were burned with no emission controls; some serve the forest management operations in their areas by cleanly burning unmerchantable wood, brush, and limbs.

Biogas Recovery

Improving environmental quality and reducing greenhouse gas emissions are primary national goals. Because methane (CH_4) is a potent greenhouse gas, biogas recovery has become a core RBEP activity. Biogas projects can also help to reduce waste disposal problems by finding productive uses for residues that otherwise would be discarded in landfills.

A key document[16] developed by SERBEP helps to provide a single source of information needed to help guide the choice of technologies for cost-effective utilization of biogas from anaerobic treatment systems was updated. The current edition takes advantage of the significant development of biogas utilization and conversion technologies during the past decade. Like its predecessor (originally published in 1988) the information in this handbook evolved from an extensive literature review and an expansive product search, and direct contact with numerous experts and vendors active in the area of biogas utilization. A list of suppliers for the equipment needed to recover and utilize the biogas from an anaerobic treatment system is contained in the appendices. The handbook is divided into seven chapters: sources and characteristics; properties; conversion; handling and storage; instrumentation and control; health, safety and environmental issues; and economics. The information in these chapters should provide the basic information needed to evaluate the design of a biogas utilization system.

Farm-Based Biogas Recovery

Since the late 1980's, a major RBEP activity has been on-farm anaerobic digestion (AD). The AD process converts organic waste materials such as farm manures into biogas, compost, and other valuable co-products. The RBEP has been the lead DOE participant in a Memorandum of Understanding (MOU) with the EPA and the U.S. Department of Agriculture's Natural Resource Conservation Service in promoting the AgSTAR Program.

Several states have worked with the RBEP to develop innovative demonstration projects and to help farmers deploy technology. One SERBEP project in Missouri[17] worked with a large company beginning a major expansion in hog production. The project helped the company evaluate the feasibility of recovering biogas from either a single- or double-cell lagoon in a waste management system constructed to Missouri Department of Natural Resources recommendations. The lessons learned also provided details about cover material, equipment, cover design and installation, off-the-bank cover design, rainwater management, fluctuating lagoon levels, and gas output. This information will be valuable for future efforts.

The Langerwerf Dairy in Durham, California, uses a plug flow anaerobic digester to convert manure from the farm's 400 dairy cow herd into biogas and other valuable co-products. The $200,000 system was initially installed in 1981 and became fully operational by 1982. Over the years, the digester accumulated large amounts of materials that reduced the digester's operating volume and, consequently, its electricity output. The Western RBEP recently helped the dairy evaluate and refurbish the system.[18]

Because the old, continuously operated anaerobic digesters have never been disassembled and the structures and equipment examined, much can be learned about their useful lifespan. Overall, the basic operating system of the dairy's digester was in good condition and required no maintenance. However, several other items did require attention or replacement. The two-layer plastic greenhouse covering the digester and the biogas collection cover both needed replacements. While some of the system materials did not last as long as design projections, the farm owners felt that the operational economics of the system had not been significantly altered.

The refurbishing required about 6 weeks, and about $50,000 in cash and in-kind labor. The digester was refilled, seeded and restarted in two weeks. At the end of the project period the system was producing about 36,000 ft3 of biogas daily and operating at 55 kW. During the first month after re-start, the farm reduced its electric bill by $850 and sold $350 worth of electricity. A key finding of the evaluation was that annual maintenance costs on an anaerobic digester had been estimated at up to 8% of capital construction costs, or $16,000 on a $200,000 anaerobic digester. The Langerwerf Dairy evaluation proved that yearly maintenance costs average less than 1% of construction costs. The final conclusion of the evaluation compared the accumulation of solids in an anaerobic digester versus that in an anaerobic lagoon. Based on 16 years of operation, the Langerwerf digester apparently retained only 1% of the solids associated with alternative waste disposal methods.

Industrial and Municipal Biogas Recovery

The AD process has tremendous deployment opportunities beyond the farm. For example, more than 35 classified industries have waste streams amenable for use in AD systems. The GLRBEP worked to demonstrate the effectiveness of a small-scale upflow anaerobic sludge blanket (UASB) for pretreating high-strength, dilute organic wastes. The project team will design, construct, and demonstrate a UASB digester using two or three high-strength industrial wastewaters.

The WRBEP actively incorporates advanced conversion technologies that use biogas as a fuel source.[19] High Plains Corporation's York, Nebraska, ethanol production facility consumes an average 4800 kW of electricity and about 192 million Btu/h of natural gas. The facility includes an anaerobic digester that reduces the chemical oxygen demand (COD) of the facility's wastewater before it is discharged to a municipal treatment plant. The biogas produced from the digester could supply a fuel cell and generate about 165 kW of electricity. Hot exhaust from the fuel cell could also supply heat to the plant boiler, thus reducing the amount of natural gas used. The fuel cell cogeneration plant that is being evaluated would be dual-fueled with biogas and natural gas. Packaged designs are available with electrical outputs of 250-, 1,000-, and 2,000-kW, and multiples.

Incorporating a direct fuel cell cogeneration plant into the York ethanol facility offers an opportunity to positively influence plant economics. The renewable energy in the biogas would be converted efficiently to electricity and thermal energy for use in the facility. Adding a fuel cell cogeneration plant to the facility would reduce combustion-related emissions. The electrochemical reactions in a fuel cell produce essentially no combustion emissions such as NOx. A 250-kW fuel cell would result in a very slight (0.35%) reduction in fuel combustion compared to the status quo at the York facility. A 6,000-kW fuel cell would produce a more substantial (8.5%) reduction in combustion emissions; at the same time it would provide 125% of the facility's electric energy requirements.

Analysis showed that the payback period is very sensitive to the price of electricity and to the capital cost of the fuel cell. It is moderately sensitive to the price of natural gas and other cost factors. The electricity price is the only parameter that has an inverse relationship to the payback period. As the price of electricity rises, the payback period shortens and the project becomes more economically attractive. The second phase of this project was recently initiated to evaluate competing biogas cleanup technologies, install the best-available cleanup technology, and to monitor digester system performance. Because biogas must be free of impurities such as hydrogen sulfide when used in a fuel cell, a key phase component will be to demonstrate that the digester and cleanup system can consistently provide clean biogas.

Another type of advanced electrical generation technology, the microturbine, is on its way to being demonstrated using biogas with the help of the GLRBEP. The project objective is to adapt microturbines from their natural gas design base, which makes them extremely fuel-flexible. This will allow the microturbine to run on the low energy content, low-pressure gases produced from biomass resources. These small, portable plants, initially ranging in size from 30-kW to 100-kW, will then be able to cleanly consume landfill gas, animal manure biogas, and gas generated from wood residues. The contractor has already designed and fabricated proof-of-concept and demonstration units. Several potential demonstration sites were investigated, and two sites in Wisconsin were selected as having the greatest potential: a county landfill and a large duck farm that operates an AD system. Negotiations are now under way to install microturbines at these sites.

Several RBEP AD projects are targeting a wide range of organic industrial and municipal residues. For example, many states now have bans on the landfilling of yard waste. Most yard waste is now composted, which often results in unacceptable odors and the release of CO_2 to the atmosphere.

The GLRBEP cost-shared the development of a pilot project with a private industry partner to develop and commercialize a yard waste AD system designed to be sited at landfills. In addition to demonstrating the yard waste digestion, the quantity and quality of the biogas for electric power generation were also evaluated. The other RBEP regions are also cost-sharing AD projects with private industry and municipalities. For example, the PNW&ARBP helped demonstrate an innovative process to greatly enhance the AD of municipal sewage sludge. The anoxic gas flotation (AGF) process concentrates anaerobic bacteria and undigested solids in the digester resulting in less sludge and more CH_4. Besides these benefits, the AGF process also allows nitrogen and phosphate to be removed cost-effectively.

Landfill Gas Recovery

A major RBEP activity for the past 5 years has been the recovery of landfill gas (LFG). Within a landfill, the AD converts the organic fraction of MSW into biogas, which is dissipated into the atmosphere. Since 1992, the RBEP has cooperated closely with the EPA to promote the Landfill Methane Outreach Program (LMOP). In several regions, the RBEP has used an innovative grant agreement with EPA to help states identify and develop solutions to technical, economic, and regulatory barriers to LFG development. The RBEP has worked jointly with the LMOP program to host state-level LFG-to-energy workshops in Florida, Georgia, Kentucky, Maryland, Massachusetts, New Jersey, New York, North Carolina, Pennsylvania, South Carolina, Washington, and Wisconsin. The RBEP is also working with the EPA on a pilot basis to educate landfill owners, operators, regulators and other stakeholders about the long-term benefits of LFG recovery.

Among others that were done by the regions, the GLRBEP worked with a project team that prepared a guide[20] for implementing state-of-the-art LFG recovery facilities. The guide included regulations for designing and operating an LFG facility, performance parameters for enhancing CH_4 production, and an economic analysis of a LFG recovery facility. The guide's purpose is to educate local government officials, landfill owners, operators, designers and regulators regarding the benefits and implementation of a LFG recovery facility.

Stakeholder Relationships and Infrastructure Development

Created at the request of its regional governors, the NRBP convened a Biomass Roundtable in 1994.[21] The Roundtable members brought a diverse range of expertise and perspectives to bear, and, after much discussion, unanimously agreed that the Northeast has a large unrecognized energy resource with considerable potential for sustainable development. That resource is biomass.

Bioenergy presently contributes about 5% of the region's energy as home heating, industrial and process heat, and through electric generation. However, in the long run, biomass can provide as much as 30% of the energy supply, creating local and regional employment opportunities instead of sending money out-of-state to pay for fossil fuels such as natural gas and oil. Further development of biomass energy offers significant opportunities to retain millions of dollars. Bioenergy could constitute an important component of the region's fuel mix, even if only small proportions of the available resources were tapped.

The Roundtable discovered that a new generation of economical bioenergy systems could help the Northeast states meet the State Implementation Plan requirements of the Clean Air Act and climate stabilization initiatives, while at the same time producing competitively priced energy. The Roundtable also stated that significant benefits would accrue through using the non-contaminated portion of the biomass that is presently going into landfills. The use of biomass will also offset air pollution from high-sulfur fuels in the region.

Current market conditions preclude the significant deployment of new electricity generation capacity using biomass. However, many market applications, such as industrial heating and institutional combined heat and power (cogeneration), are both economic and environmentally sustainable. Furthering these applications will help build an infrastructure that can prepare the way for the advanced bioenergy technologies that will be able to economically compete with fossil fuels.

To a great extent, maximizing the benefits of bioenergy and minimizing the costs is a matter of timely support for and strategic investment in specific niches and applications. This is largely an opportunity for the private sector. Yet the Roundtable found that the governors could play a critical role in creating the political, regulatory, and institutional conditions under which environmentally appropriate developments can be pursued cost-effectively. Among other items, gubernatorial leadership can increase public awareness of the opportunities for developing biomass and can work to streamline regulatory processes that today are barriers to biomass projects.

In 1995, individual representatives from various regional bioenergy stakeholder groups—including private industry, academia, environmental groups, paper and lumber companies, farmers, utilities, government, trade associations, equipment manufacturers, and others—convened to form the Southeast Bioenergy Roundtable.[22] Representatives from more than 30 groups participated. They met periodically to identify and review issues and concerns related to bioenergy development and to develop consensus strategies to allow widespread use of bioenergy in an environmentally, economically, and socially responsible manner. Although the resultant report is primarily a strategy document, it also summarizes the potential for bioenergy in the Southeast, lists the issues and concerns identified by the Roundtable, and presents evidence in support of the consensus strategies developed to address these challenges. Its intended audience encompasses all entities involved in the development of bioenergy in the Southeast. These entities may use this product to create awareness of the issues and concerns, to formulate policy, or as a source of recommendations to address issues and concerns.

Feedstock Development

Large-scale bioenergy use will require the development and demonstration of environmentally acceptable energy crops and cropping systems for producing large quantities of low-cost, high-quality biomass feedstocks. A large-scale willow demonstration in New York was progressing well, but it took assistance from the NRBP to move the "technology" out of New York and to demonstrate it in Pennsylvania, Delaware, and New Jersey. Through the efforts of NRBP state representatives, five willow demonstrations will eventually be established.

The latest willow "site trial" demonstrations were established in spring 1999. In April, with the help of more than 50 volunteers, a new site was established at the Blackbird State Forest in Delaware. The 2.5-acre site contains more than 15,000 cuttings representing 14 species of willow. Later in 1999 an additional three acres of switchgrass will be planted. The site trial is being funded by a grant from the USFS and managed by the state's biomass program. In May, a second Pennsylvania site trial was established in Tioga County. This site trial complements the site established last year. More than 8,000 willow cuttings were planted on a 1.4-acre plot. The State's Department of Agriculture was joined by Farm Bureau officials and other research scientists to plant the site. A third Pennsylvania site trial is scheduled for planting in spring 2000. These site trials provide valuable information to the Oak Ridge National Laboratory on productivity in differing climates and soil types, as well as introducing the concept of bioenergy crops to farmers in these states.

The GLRBEP is working to evaluate the economic and agronomic feasibility of establishing switchgrass on marginal cropland in southwestern Wisconsin for electrical and liquid fuel production. [23] The project will examine the costs to cultivate and harvest switchgrass, preferred management practices, crop financing, crop markets, and potential farmer contracts.

Approximately 175 acres have been enrolled in the project and switchgrass has been planted on sites ranging from 3 to 50 acres. Each site has been monitored monthly since planting. The switchgrass plots show varying degrees of germination and plant growth. Site preparation seems to be a key factor in yields. Educational outreach "field days" have been held quarterly and will continue throughout the project. A videotape from field days has been completed. Initial results have been positive for growing switchgrass on marginal sites. The contractor hopes to market the switchgrass to a newly constructed wood-fired prison boiler.

Farmers have also been supported by the SERBEP in planting energy crops.[24] Starting in June 1997, approximately 300 acres of land were plowed, disc harrowed, and cultipacked in preparation for seeding at two sites in Alabama. Some of the land had been in row crops; the rest in grazed pasture. At one site, the terrain ranged from bottomland, through gentle slopes, to some fairly steep, rocky sections that were totally unsuitable for annual cropping. At the second, the land was mostly gently sloping and suitable for rowcropping. The switchgrass stands were variable at both sites, but about 200 acres were successfully established. A yield of three tons per acre was expected to be available for harvest in 1998, and considerably more was expected for 1999. The material harvested in 1998 was to be covered with plastic to prevent deterioration and would be combined with the 1999 harvest for a co-firing test at a nearby electric power plant.

Educational Outreach

Beginning in 1993, the Washington State University (WSU) Energy Program received a grant from the EPA to prepare a greenhouse gas emissions inventory for Washington State for the base year 1990. Since that time WSU has used a combination of resources, including PNW&ARBP funds, to continue tracking greenhouse gas emissions in the state. Other state agencies now rely on WSU to provide the most current inventory. The major gases tracked include CO2, NOx, CH4, and perfluorocarbons. The major sources or sinks include fossil fuel and biomass combustion, landfills, cement production, enteric fermentation, animal manure, fertilizers, aluminum production, and forest growth. The energy related emissions are updated annually and the other gases every 5 years.

The purpose of the tracking is to identify the major sources of emissions and trends. The transportation sector accounts for 60% of the energy related emissions. This is much higher than the national average because most of the state's electricity comes from hydroelectric and nuclear generation. The data also indicates that forests are net sinks for CO2. Knowing where greenhouse gas emissions originate helps to better identify areas where meaningful reductions could take place. These areas include animal manure management, agricultural practices, and the use of biomass-derived transportation fuels.

In cooperation with the Texas Renewable Energy Industries Association (TREIA), WRBEP sponsored three one-day seminars highlighting the opportunities for bioenergy use in Texas. The overall goal was to educate a broad range of participants on bioenergy areas promising the greatest promise for near-term project development. The three were biogas production and electric generation from livestock manure, LFG capture and energy production from landfills, and biofuels production. In addition to educating the attendees that there is sufficient potential for bioenergy technologies to warrant their keeping abreast of developments and thinking proactively about finding ways to use them in the future, TRIEA also had the objective of stimulating the attendees into building actual projects. Not only did the seminars attract more participants than hoped, additional follow-up by TRIEA indicates that many are seriously considering moving forward with project development.

Other types of outreach can also play a significant role in helping to educate business and policy decision-makers on the opportunities for bioenergy. SERBEP produced a sourcebook [25] directed specifically toward economic developers in the Southeast. It focuses on bioenergy resources, economics, financing, and other pertinent information, and provides economic developers with the comprehensive information, analytical tools, and references they need to be effective advocates of biomass energy. This document also serves to educate the reader on the subject of bioenergy and provides a continuing reference. State maps that identify the availability of various biomass resources by county are also provided. In addition, one chapter that includes case studies of six successful bioenergy projects in the Southeast.

The NRBEP has also actively addressed the issues associated with financing large-scale bioenergy projects in its region.[26] In particular, the NRBP was interested in addressing why bioenergy projects that appeared to be both technically and economically feasible were not moving forward to full implementation, and whether the impediment was the lack of capital financing. For the study, bioenergy projects initially included virtually all types and sizes of projects employing biomass as a feedstock to produce a useful and economically attractive and marketable product. Before the study proceeded, it was hypothesized that:

- Technically sound projects were proceeding through initial feasibility assessments and pilot plant development, but are not being developed into full-scale projects
- Projects are not gaining access to available and affordable capital, which precludes the development of bioenergy projects
- Market bias against these projects is due to a lack of understanding of the technologies involved and the potential benefits of implementing such projects
- State funding programs cannot or will not provide effective support for these types of projects
- With appropriate information and education, conventional sources of financing would become available to fund these projects

As the study progressed, effort also focused on the financing needs of larger projects, with capital costs ranging from $10 to $100 million. This component also dealt with the financing interests and criteria of the conventional lender that could make a meaningful and obvious contribution to the development of the bioenergy market, and that would produce tangible economic development benefits, particularly in the form of job creation.

Putting the Puzzel Pieces Together: A Brief Case Study

Just as the longest journey begins with the first step, often a state grant project grows into a regional technical project that finally transcends into a national effort. For example, the Montana Department of Environmental Quality (MDEQ) and the PNW&ARBP developed the Snowmobile in the Park Project. The objective was to demonstrate the use of bio-based fuels and lubricants as a method to improve the efficiency and emissions of two-stroke snowmobile engines in and around YNP.

Unless these pollution and potential health problems are reduced, snowmobiling in the YNP may eventually be regulated or curtailed. Laboratory tests compared snowmobile engine emission differences between biomass-based fuel and lubrication oils to those from traditional fuel and lubes. The tests found E-10 reduced CO emissions by 9%-20%, PM by 25%, and unburned HC by 10%-16%. Lubrication oils tested included animal and plant oils and their derivatives. Some of the bio-based lube oils reduced PM by 70%. Products shown in laboratory tests to reduce emissions, increase biodegradability, and meet manufacturers' specifications were demonstrated over two seasons in 100 NPS snowmobiles in YNP.

The results persuaded the NPS to switch to E-10 year-round for all its gasoline-powered vehicles. West Yellowstone snowmobile and snowcoach operators also voluntarily switched to gasohol and environmentally friendly bio-based lube oils to reduce emissions. Industry representatives and others feel that the project is helping set policy for the use of snowmobiles. For example, industry and government officials in Michigan, California, and Sweden are using the results to evaluate impacts and reduce pollution in other environmentally sensitive areas.

MDEQ is also spearheading a project to demonstrate the use of biodiesel in NPS vehicles in YNP. With visitation increasing yearly, there is a need for more efficient transportation, and reduced pollution, odors, and smoke from tourism-related transportation. The use of biodiesel could be part of the remedy for the pollution generated by motor vehicles in YNP.

Building on this effort, the PNW&ARBP and its participating states developed the *Green Corridors Project* to help spread the use of environmentally friendly products and practices found successful in YNP to other areas. The goal, which can be accomplished by making it easy for visitors to use environmentally friendly products such as E-10, is to reduce pollution and possible health impacts caused by tourist activities.

The *Green Corridors Project* aims to not only raise awareness for using new environmentally friendly products, but also to prevent non-biodegradable products from being released into the environment. Actions taken to prevent pollutants from entering the environment is called pollution prevention (P2). A first step in a P2 program is conducting an inventory of potentially polluting materials and evaluating how those materials are used and disposed of.

The *Green Corridors Project*, using trained specialists, performs environmental and safety walk-through inspections of participating service stations throughout Montana, Wyoming and Idaho. As a result, service stations, in and around the Yellowstone gateway corridors, are now using fuels, lubricants, and practices that are environmentally friendly, while improving employee and consumer safety. The program emphasizes the benefits of increased employee safety and helps reduce employee turnover for service stations.

Given the success of these initiatives, the RBEP demonstrated its capability to work with the NPS and its ability to provide objective information on biofuels to federal fleet managers and to the general public. For 1999, the RBEP proposed a national strategy to assist NPS managers in their effort to curb transportation-related environmental impacts in parks and to increase the availability of alternative fuels in the gateway communities leading into National Parks.

The focus of the *Green Fuels and Clean Parks Initiative* is to bring biofuels into common usage within targeted National Parks and state recreational areas in the United States. The emphasis is on the NPS, USFS lands, and other key recreational areas associated with state and federal lands. A secondary objective is to foster the use of biofuels within federal and state fleets consistent with federal energy and environmental policy requirements. A third objective is to encourage the competitive availability of biofuels, such as ethanol and biodiesel, within the nation. A final objective is to develop the infrastructure to serve the public park visitors and the local residents with a biofuel option in the areas surrounding the National Parks.

These demonstration projects can provide valuable information on the performance of alternative fuels and provide an excellent opportunity to heighten visibility and to educate the public on the benefits of using alternative fuels. As of July 1999, the following projects have been tentatively selected:

- Channel Islands NP, where B-100 will be demonstrated in a research boat.
- Everglades NP, where B-100 will be demonstrated in selected vehicles and stationary equipment.
- Hawaii Volcanoes NP, where B-100 and biodiesel blends will be used in utility and maintenance equipment, and in an engine-generator.
- Mammoth Cave NP, where E-85 will now be used by all park vehicles.
- Picture Rocks National Lakeshore, where B-20 and bio-lubricants will be used.
- Scotts Bluff National Monument, where B-20 will be demonstrated in a colder climate.
- Sleeping Bear Dunes National Lakeshore, where B-20 and bio-lubricants will be used.
- Voyageurs NP, where B-20 will be demonstrated in a colder climate.
- Yellowstone NP, where the use of higher biodiesel blends (B-50) will be demonstrated.
- Yosemite NP, where a hybrid diesel-electric bus using B-20 will be demonstrated.

Conclusion

Of all DOE's programs, the RBEP is positioned closest to the ultimate bioenergy customer. Therefore, the RBEP is ideally suited to act as a bridge, helping translate customer needs to DOE's programs and bringing innovative solutions from the laboratory to commercial application.

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